RECEIVED
JUL 11 1947
LIBRARY

I. C. 7403

JUNE 1947

UNITED STATES
DEPARTMENT OF THE INTERIOR
J. A. KRUG, SECRETARY

BUREAU OF MINES
R. R. SAYERS, DIRECTOR

INFORMATION CIRCULAR

# RECENT ENGINEERING DEVELOPMENTS IN SWITZERLAND ON GAS TURBINES AND STEAM GENERATORS

BY

HAROLD J. ROSE

Generated on 2024-09-19 17:48 GMT / https://hdl.handle.net/2027/osu.32435030643837
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google

Digitized by Google

Original from
THE OHIO STATE UNIVERSITY

# FOREWORD

Dr. H. J. Rose, Vice President and Director of Research, Bituminous Coal Research, Inc., while on a technical mission to Europe after the close of the war, was permitted to visit neutral Switzerland in order to obtain information on recent fuel developments in that country. Dr. Rose was a member of the Solid Fuels Mission of the Technical Industrial Intelligence Committee, which cooperated with a counterpart British committee. This mission operated under the direction of a steering committee headed by Dr. C. J. Potter, Deputy Solid Fuels Administrator, and consisted of J. W. Buch, Thomas Fraser, L. L. Newman, L. D. Schmidt, and H. F. Yancey of the Bureau of Mines; H. H. Lowry, Director of the Coal Research Laboratory, Carnegie Institute of Technology; H. J. Rose, Vice President and Director of Research, Bituminous Coal Research, Inc., and F. H. Reed, Chief Chemist, Illinois Geological Survey.

The members of the mission prepared over 50 reports, which, together with microfilms of supporting data obtained in the course of investigations, are on file at the Bureau of Mines, Washington, D. C., where they are available for public examination. The Office of the Publication Board in the Department of Commerce is prepared to furnish photolith copies, photostats, or microfilm reproductions of all declassified reports. A Bibliography of Scientific and Industrial Reports is issued weekly by the Department of Commerce, Office of the Publication Board, and is sold by the Superintendent of Documents, Government Printing Office, Washington 25, D. C., on a subscription basis. An initial payment of $10 will provide for approximately 9 months, and subscribers will be notified when additional remittance is necessary. All subscriptions will begin with volume 1, No. 1, unless ordered otherwise. The Bibliography covers all materials and subjects and gives instructions for obtaining the desired items.

Although the purpose of this mission was to obtain information from enemy countries, the developments in neutral Switzerland are considered to be so important that they should be brought to the attention of the American public. This report was first published as FIAT report 509. The preparation of this report by Dr. Rose and the splendid cooperation of the Swiss engineers in supplying him with data are appreciated.

A. C. FIELDNER, Chief,
Fuels and Explosives Branch.



Generated on 2024-09-19 17:46 GMT / https://hdl.handle.net/2027/osu.32435030643837
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

I.C. 7403,
June 1947.

INFORMATION CIRCULAR

UNITED STATES DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

# RECENT ENGINEERING DEVELOPMENTS IN SWITZERLAND ON GAS TURBINES AND STEAM GENERATORS[1]

By Harold J. Rose[2]

CONTENTS

| | Page |
|---|---|
| Introduction | 2 |
| Purpose and scope of investigation | 2 |
| Dates of investigation and personnel | 3 |
| Summary | 3 |
| Report I. - Brown, Boveri & Co., Ltd. | 6 |
| Location of target | 6 |
| Date of investigation | 6 |
| General information and personnel met | 6 |
| Information obtained on products | 7 |
| Early combustion turbines built by B. B. C. | 7 |
| Coal-fired turbine experiments | 7 |
| Gas-turbine publications since the war began | 8 |
| Gas-turbine locomotive | 9 |
| Summary of B. B. C. gas-turbine construction | 10 |
| Velox steam boilers for oil and gas | 10 |
| Coal as fuel for velox boilers | 11 |
| Combined heating and power plants | 12 |
| Heat pumps | 12 |
| Projected new thermal laboratory | 14 |
| Conclusions | 14 |
| Documents and publications | 14 |
| Report II. - Escher Wyss Engineering Works, Ltd. | 17 |
| Location of target | 17 |
| Date of investigation | 17 |
| General information and personnel met | 17 |
| Information obtained on products | 17 |
| Early water and steam turbines | 17 |
| Aerodynamic turbine | 18 |
| Turbine performance tests | 18 |
| Solid fuel and derived gaseous fuels for turbines | 19 |

1/ The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from Bureau of Mines Information Circular 7403."

2/ Vice president and director of Research, Bituminous Coal Research, Inc.



Generated on 2024-09-19 17:48 GMT / https://hdl.handle.net/2027/osu.32435030643837
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

CONTENTS-Cont'd.


| | Page |
|---|---|
| Report II. - Escher Wyss Engineering Works, Ltd.-Continued | |
| Information obtained on products - Continued | |
| Availability of aerodynamic turbines | 20 |
| Combined heating and power plants | 21 |
| Heat pumps | 21 |
| Research activities | 22 |
| Conclusions | 22 |
| Documents and publications | 23 |
| Report III. - Sulzer Bros., Ltd. | 25 |
| Location of target | 25 |
| Date of investigation | 25 |
| General information and personnel met | 25 |
| Information obtained on products | 25 |
| Heat-engine developments | 26 |
| Constant-pressure combustion turbine | 26 |
| Monotube high-pressure steam generators | 27 |
| Combined heating and power plants | 30 |
| Heat pumps | 31 |
| Radiation heating from ceilings | 31 |
| Research laboratories | 32 |
| Conclusions | 32 |
| Present Swiss views on energy problems | 33 |
| Documents and publications | 33 |
| Appendix | 38 |
| Personnel of team | 38 |


## INTRODUCTION

### Purpose and Scope of Investigation

The purpose of this investigation was to determine what progress has been made in Switzerland during the war years in developing equipment for the more effective utilization of coal. Particular attention was given to developments that may permit the use of coal for firing gas turbines.

Additional subjects of interest to the Solid Fuels Subcommittee included:

Experimental burning of coal under pressure in Velox boilers.

Recent commercial developments in Monotube high-pressure boilers fired with coal.

Combined heating and power plants.

Commercial development of the "heat pump" for space heating and other uses.

Comfort heating by radiation from ceilings.



Generated on 2024-09-19 17:49 GMT / https://hdl.handle.net/2027/osu.32435030643837
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

Three Swiss firms that have been prominent in designing and manufacturing equipment of this sort were visited, and the results of the interviews are presented in the following report under the individual firm names, arranged in alphabetical order, namely:

I. Brown, Boveri & Co., Ltd.
II. Escher Wyss Engineering Works, Ltd.
III. Sulzer Brothers, Ltd.

## Dates of Investigation and Personnel

Interviews with these companies covered the period September 18 to September 27, 1945; and were made by Dr. Harold J. Rose (United States). It is understood that other United States missions have visited Switzerland with regard to gas turbines. However, so far as is known, the above investigator has been the only one who was primarily interested in the use of coal (which constitutes 98.9 percent of the United States' known reserves of mineral fuel, according to recent Bureau of Mines estimates of coal, petroleum, natural gas, and oil-shale reserves).

Most of the Swiss engineers interviewed spoke English well. Many of them had either worked in America or had traveled on business in English-speaking countries. Company publications are commonly issued in English, German, and French editions, though some of the publications were not available in English.

## SUMMARY

The economic situation in Switzerland during recent years has resulted in theoretical studies, engineering development work, and many commercial installations of ingenious methods for using energy more efficiently. The purpose of the present investigation was to learn of recent Swiss developments for the more effective use of coal, which comprises 98.9 percent of the remaining known mineral-fuel reserves of the United States.

## Gas Turbines

Each of these three firms is actively interested in gas turbines.

Brown, Boveri & Co., Ltd. is the only one that is actively experimenting with the use of coal for firing gas turbines. Considerable progress has been made experimentally in (a) burning coal under pressure to obtain combustion gases with a reduced content of solid particles and (b) designing turbine blades that show minimum erosion from such particles. Engineering tests now in progress must probably be continued for some time before the company would be justified in designing a full-sized coal-fired combustion turbine plant for commercial trial and further development under practical conditions.

About 40 BBC-type gas turbines powered by combustion gas from the Houdry process or by oil for power generation have been built throughout the world or are on order. This does not include gas turbines used in connection with Velox boiler plants. The oil-fired gas-turbine locomotive built for the



Generated on 2024-09-19 17:50 GMT / https://hdl.handle.net/2027/osu.32435030643837
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

Swiss Federal Railways was accepted after the required period of trial in actual service. BBC combustion turbines were built in Germany for blast-furnace gas firing at metallurgical plants.

Escher Wyss Engineering Works, Ltd. - This company has developed a closed-circuit "aerodynamic turbine" in which the working medium is air circulated under pressure. This feature permits the design of units of large output and of nearly constant efficiency over a considerable load range. Combustion products do not pass through the turbine, and any fuel can be used, provided heating surfaces in the air heater can be kept satisfactorily clean and in good condition. Company publications contain references to the use of coal with a thermal efficiency as high as 35 percent, as a possibility after a period of future development.

The only aerodynamic turbine constructed to date is the 2,000-kw. development unit at the company's plant. Performance tests in which the maximum average temperature of air entering the turbine was 1,288° F. and maximum pressure was 343 lb./sq. in. showed a thermal efficiency of 31.5 percent at full load and 29.6 percent at half load, based upon the net heating value of the oil fired.

Subject to establishing a satisfactory source of supply for alloy air-heater tubes, the company is prepared to accept orders for aerodynamic turbines of 6,000, 12,000 or 25,000 kw. size. Still larger units are envisioned, such as a single-shaft output of 100,000 kw. with maximum air pressure not over 30 atm.

Sulzer Bros. - This company has under construction a 7,000-s.h.p., oil-fired, marine combustion turbine with its own type of circuit for trial purposes. Very little has been released on the design of this gas turbine. It is said to have certain advantages of a closed circuit without the necessity of a large air-heating chamber. Not much consideration has been given as yet to the use of coal as fuel for this turbine.

## Compact Steam Generators

Two novel types of steam generators (boilers), which were introduced before the war, have had further development and commercial acceptance.

Brown, Boveri Velox steam generator. - In this type of boiler, fuel is burned under a pressure of 2 to 3.5 atm. absolute, and the combustion products pass through a gas turbine, which drives a compressor that supplies the required air. Steam is commonly produced at 25 to 35 atm. and 425° to 450° C. (797° to 842° F.).

To date, only oil and gas fuels have been used in Velox boilers, but Brown, Boveri & Co. have been studying the combustion of coal under pressure for several years. Development work on pulverized-coal firing of Velox boilers appears to be approaching a point where construction of a full-scale unit for industrial trial should be considered. This would promise a compact plant of high thermal efficiency, quick starting time, flexible automatic operation, and stack gases free of smoke and fly ash.



Generated on 2024-09-19 17:51 GMT / https://hdl.handle.net/2027/osu.32435030643837
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

Sulzer monotube steam generator. - This design is intended for steam pressures above 80 atm. Most of the existing plants superheat to about 500° C. (932° F.), and the present maximum working pressure is 140 atm. About 50 units have been built in eight European countries, 42 of which were fired with solid fuel - mostly pulverized coal - or by means of traveling grates. Low-grade fuels with very high ash or moisture content have been used successfully.

These plants offer very high-pressure steam generation in compact plants with automatic regulation of feed water, pressure, and temperature (of superheated steam) and prompt synchronization of heat input and removal under varying load conditions when using a wide variety of solid fuels. As soon as known alloys are available, the company is prepared to build Monotube boilers to produce steam at 600° C. (1,112° F.) and 160 atm. In a large plant, with reheat to the same temperature, thermal efficiencies up to 36 percent are expected.

Combined heating and power plants. - All three of the Swiss companies are interested in installations in which the over-all efficiency of heat utilization is increased considerably by using the energy partly for power and partly for heating purposes.

For example, steam may be used to generate power in a back-pressure steam turbine or steam engine, and the exhaust steam is then used for process work or comfort heating. Or the cooling water from certain gas-turbine plants may be drawn off at a temperature high enough for heating purposes or hot-water supply. The use of a heat pump in connection with power plants has also been considered.

Heat pumps. - Owing to a favorable combination of circumstances in Switzerland, "heat pumps" have received much commercial development recently for comfort heating and cooling as well as for industrial use. In this process, electric power is used to drive a machine that extracts heat from cold lake or river water and delivers it at a temperature high enough for comfort heating or other purposes.

In typical examples, two-thirds of the useful heat comes from the water supply, and only one-third must be supplied by the electric power used. With the lower temperatures used in "panel" or "radiation" heating, it is said that as little as one-fifth of the energy needs to be supplied by the electric current. In industrial evaporation processes having much smaller temperature differentials, still higher ratios of useful heat to power input are well-established.

In Switzerland, hydro-electric power normally is used for this purpose, and the heat-pump principle is used to multiply the heating effect of the electricity because of a coal shortage resulting from the war. It is obvious that electricity produced from coal could be used to operate heat pumps, also. The relative efficiency and cost of producing electricity and heat from coal do not encourage this idea in general. However, there will doubtless be cases where conveniences, cleanliness, or other reasons would influence



Generated on 2024-09-19 17:49 GMT / https://hdl.handle.net/2027/osu.32435030643837
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

choice of a heat pump powered by electricity from coal instead of burning the coal directly for heat.

The recent heat-pump installations in public and private buildings in Switzerland are most interesting, but Swiss engineers are conservative as to commercial markets for such equipment. Over a large area such as the United States, with abundant coal reserves, only a limited percentage of cases might justify consideration of the heat pump, and many of these cases would be economically feasible only when supplemented by more conventional methods of heating or cooling with energy derived from coal.

Radiation heating from ceilings. - The Sulzer Co. has made a number of comfort-heating (and cooling) installations in public and private buildings by using pipe coils embedded in the ceilings.

Research facilities. - The companies visited maintain technical staffs and laboratories for research and development work in thermal engineering, and they also collaborate with faculty members of Swiss technical schools. Sulzer Bros. have just completed a large and well-equipped laboratory building, which supplements their previous laboratories. Brown, Boveri & Co. expect to erect a separate thermal laboratory building as soon as the necessary materials can be obtained.

Documents and publications. - About 800 pages of technical publications, reports, etc., obtained from these companies (which are referred to individually throughout this report) have been filed and microfilmed for convenient reference.

## REPORT I. - BROWN, BOVERI & CO., LTD.

### Location of Target

The main office and factory of Brown, Boveri & Co. is in Baden, Switzerland, about 15 miles northwest of Zurich. The plant is just west of the railway station in Baden.

### Date of Investigation

The investigation occupied 2-1/2 days and was made on September 18, 19, and 20, 1945.

### General Information and Personnel Met

The following persons were met:

Dr. Eng. Adolf Meyer, director of the Heat Engineering Section, which deals with research, design, and testing of thermal machines.

C. Seippel, assistant to Dr. Meyer and formerly in charge of the gas turbine department. (The present head of this department is Mr. K. Niehus.)



Generated on 2024-09-19 17:46 GMT / https://hdl.handle.net/2027/osu.32435030643837
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

Hans Dietler, who is in direct charge of the testing and development of coal-fired equipment.

Paul R. Sidler, American representative of B.B.C., who was in Baden at the time.

Walter Thut, who expects to go to the New York office soon to assist Mr. Sidler.

A number of other engineering executives and engineers of this company also were met. No attempt was made to discuss the electrical equipment manufactured by this company, but some of the research, testing, and manufacturing facilities for electrical equipment were seen incidental to the investigation of the subjects covered by this report.

## Information Obtained on Products

### Early Combustion Turbines Built by B.B.C.

Dr. Meyer has described the early history and development of the gas turbine (see B.B.C. Item 1, in list of documents and publications at the end of this section. These documents have been microfilmed on T.O.M. reel 139, original designation SF 6.) In 1909 to 1913, Brown, Boveri & Co. built and tested, to the order of Dr. Holzwarth, a gas turbine of the explosion type, which had a net output of about 200 hp. In 1928, they built a Holzwarth turbine with modified cycle, which was operated with blast-furnace gas in a German steel plant and led to an order for a larger, 5,000-hp., turbine from the German Brown, Boveri factory.

Since 1930, B.B.C. has used gas-turbine and compressor sets as an auxiliary to Velox boilers in which oil or gas fuel is burned under pressure produced by a compressor powered by the expansion of flue gases flowing continuously through a gas turbine. Since about 1936, gas turbines designed by this company have been used on the hot exhaust gases of the Houdry oil-cracking process. In 1938 an oil-fired gas turbine of 4,000 kw. size was ordered for the city of Neuchâtel, Switzerland, for emergency (bomb-proof) power supply. In 1941 an oil-fired gas-turbine-powered locomotive was completed for the Swiss Federal Railways. (See B.B.C. Items 1, 2, 3, 8, and 18.)

### Coal-Fired Turbine Experiments.

Realizing the potential economic advantages of using coal as a fuel for continuous-combustion gas turbines, Brown, Boveri & Co. have been studying this problem for about 3 years. The writer was privileged to discuss this subject with them at some length, and from the test apparatus and results seen, it is evident that they have made considerable progress along several lines. These experiments are still in progress and have not reached the stage where a definite prediction as to their outcome is justified.

The engineering executives of the company feel that there is a good possibility that several months more of testing will bring the coal-fired



Generated on 2024-09-19 17:51 GMT / https://hdl.handle.net/2027/osu.32435030643837
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

combustion-turbine development to the point where consideration of a full-sized experimental unit for industrial trial will be justified. Encouraging progress has been made in producing combustion gases that have a reduced content of fly ash when leaving the furnace chamber, and also in designing turbine blades that show far less erosion than formerly. However, tests now in progress or definitely planned must be completed before these developments can be evaluated.

Brown, Boveri & Co. have not as yet published information on their experiments on coal firing of gas turbines. The following brief reference to the use of coal is from page 6 of B.B.C. Item 7, written by Dipl. Ing. H. Pfenninger of B.B.C. in 1944.

> (a) Power Plants for Producing Electrical Energy. The gas turbine can, for the present, only be employed with liquid or gaseous fuels. Experiments are now being made with pulverized coal, but these have not yet been completed. The range of load of the gas turbine lies here between 1,000 and about 20,000 kw.
>
> Recently, the problem of gasification of coal in gas generators has been again taken up. As the gas turbine is the cheapest form of power plant, the application of the gas generator is likely to be most remunerative here, so that the possibility of burning also solid fuels already exists today.

A paragraph in a German-language article (B.B.C. Item 6, p. 10) contains about the same comments on coal for combustion turbines.

Gas Turbine Publications Since the War Began

Copies of several publications dated later than 1939 were obtained.

Prof. Dr. A. Stodola of Zurich has summarized load tests of a B.B.C. combustion gas turbine of 4,000 kw. size constructed as a stand-by bomb-proof power station for the town of Neuchâtel, Switzerland. (See B.B.C. Item 4.) As this was intended only for emergency use, refinements such as a heat exchanger between exhaust gases and combustion air were omitted. The electrical output of the generator had a heat equivalent of 17.38 percent of the fuel in a test in which the inlet temperature of gas to the turbine was 1,067°F. or 1,026°F. (depending on method of measurement), and the temperature at the gas turbine outlet was 532°F. Gas oil was used as fuel, and no cooling water was required. Possible methods of increasing the efficiency are summarized in the paper.

Dr. W. G. Noack has discussed new methods of compressing and heating blast air for iron-blast furnaces. (See B.B.C. Item 5.) This paper discusses various combinations in which the gas turbine is either the main machine or else merely an auxiliary for fulfilling the "Velox" principle, in which blast-furnace gas is burned under pressure with very high rates of flue-gas flow, the necessary combustion pressure being obtained by a compressor coupled to a gas turbine driven by the flue gases. A Velox steam boiler or Velox



Generated on 2024-09-19 17:46 GMT / https://hdl.handle.net/2027/osu.32435030643837
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

blast heater may be used. Some cost comparisons are included. Dipl. Ing. H. Pfenninger of B.B.C. wrote an article in German in 1944 on the present position and economic outlook of the combustion turbine (B.B.C. Item 6a). A translation of this article has been made. (B.B.C. Item 6b.)

An article in English by the same author in 1944, entitled "Present-Day Possibilities of the Combustion Turbine" (B.B.C. Item 7) is somewhat shorter and contains fewer diagrams than the preceding reference. It states that combustion turbines built up to the present time attain efficiencies of about 20 percent, which is sufficient only for special applications. By using air preheaters that are large enough, efficiencies of about 30 percent may be attained. Curves are shown for computing the most economical efficiency, allowing for amortization of heat-exchanger costs and saving in fuel. The advantages of a single-stage combustion turbine are compared with (a) a steam plant, (b) a Diesel-engine plant, and (c) a closed-cycle hot-air plant. The single-stage combustion-type turbine can be built today for outputs of 1,000 to 6,000 kw. No cooling water is required.

The two-stage combustion turbine has an efficiency of 21 percent without heat exchangers and 30 percent or more with heat exchangers. It can be started up from cold in about 10 minutes. This type consists of two compressors and two turbines in series. An order for a 10,000-kw. plant of this type has been received by B.B.C. They require one-fifth to one-tenth the cooling water of a steam turbine plant of the same output. Various fields of gas-turbine applications are discussed briefly in the paper.

Gas-turbine power plants are discussed in a German-language article, which is accompanied by a 2/3-page summary in English, as well as English titles for the illustrations (B.B.C. Item 21). This discusses caloric power plants as emergency supplementary, and combined heating and power plants, with various cost comparisons. It includes the use of gas turbines, Velox boilers and conventional steam plants. Costs are estimated for Swiss conditions for a 50,000-kw. power plant. The lowest power cost is shown for powdered coal fuel and a steam turbine; next, coal producer gas burned in a gas turbine; then, oil fired in a Velox boiler with a steam turbine; and, lastly, oil fired in a gas turbine. Five-year fuel storage is cheaper for coal than for oil. The paper states (p. 80):

> These tables show, that in modern caloric power plants the electric energy can even in Switzerland be produced at costs as low as in hydraulic accumulating plants.

Gas-Turbine Locomotive

The gas-turbine locomotive (oil-fired) constructed by B.B.C. for the Swiss Federal Railways in 1941 was seen by the writer at Münchenstein near Basle, Switzerland. It had been run for a year in regular service as the condition for acceptance. After acceptance the locomotive was laid off on account of fuel-oil shortage.



Generated on 2024-09-19 17:51 GMT / https://hdl.handle.net/2027/osu.32435030643837
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

Negotiations are now underway between the Swiss and French governments, which may result in the loan of this locomotive to France for regular service on a much longer run than has been available in Switzerland.

"The First Gas-Turbine Locomotive" is the title of a paper by Dr. Ad. Meyer (B.B.C. Item 8), which describes this locomotive in a general way, including the sequence of operations in a typical run. The economic prospects of the gas-turbine-electric locomotive are discussed by comparing it with steam and Diesel-electric locomotives. The paper is based upon an oil-fired gas turbine. It is stated on page 12:

> If we succeed in solving the problems inherent to the pulverized-coal gas turbine, the future of the gas-turbine locomotive would be very bright indeed. We have a turbine developing 2,000 hp. of this type on our test bed, and the results obtained justify our hopes of being able to put similar units on the market in the near future.

The reference B.B.C. Item 9, dated July 1945, gives additional specifications and performance data on the first gas-turbine locomotive constructed for the Swiss Federal Railways. The maximum output of the set measured at the coupling of the generator is 2,200 hp. at 5,200/812 r.p.m. The power for starting up is produced by a Diesel generator set of 100 hp. The electric transmission is the same as for Diesel-electric locomotives. In the shop test, thermal efficiency was 16 percent at full load and 17.7 percent at 3/4 load. In the period of regular service before acceptance, ended July 18, 1944, the locomotive ran 50,000 km. (31,000 mi.). During the 297 days, the combustion chamber was in operation for 1,614 hours, and 1,560 starts were made. A total of about 50 liters (13.2 gal.) of lubricating oil was consumed or lost in overhauls during these tests.

Summary of B.B.C. Gas Turbine Construction

It is understood that 3 gas turbines have been built for power uses and 28 of the B.B.C. type for use in Houdry petroleum-processing plants. Eight more gas turbines are on order with B.B.C. at present. The above figures do not include the gas turbines used in Velox pressure-combustion installations or blast-furnace gas turbines built by the German B.B.C.

Velox Steam Boilers for Oil and Gas

Dr. Meyer stated in 1939 (p. 5 of B.B.C. Item 1):

> The work done by Messrs. Brown, Boveri & Co. in connection with the Holzwarth gas turbine resulted in the development of the Velox boiler, whose principle is now well known to most engineers, but which nevertheless is referred to again here (fig. 8), because the experience gained with it led back to the combustion turbine. The Velox steam generator is a boiler fired under pressure, the pressure being produced by a compressor driven by a gas



Generated on 2024-09-19 18:03 GMT / https://hdl.handle.net/2027/osu.32435030643837
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

turbine actuated by the exhaust gases of the boiler. Part of the pressure produced in the compressor is used to maintain high gas velocities in the heat-transmitting parts of the boiler, thus ensuring high rates of heat transfer. The remainder of the pressure head is used to drive the gas turbine.

Existing publications deal with oil- or gas-fired Velox boilers. A peak-load plant for Oslo, Norway, is described in B.B.C. Item 10. The burning of gas under pressure (including blast-furnace gas) is briefly discussed in B.B.C. Item 11. A stand-by and peak-load power station built near Berne, Switzerland, in a horizontal tunnel is described in B.B.C. Item 12..

A general description of Velox steam generators for land purposes is given in B.B.C. Item 13. This may be consulted for such items as characteristics and advantages, working principle and design, automatic governing, safety devices, starting time required, efficiency, constructional features, and applications. Combustion takes place at a pressure of 2 to 3-1/2 atmospheres, absolute, in a combustion space one-tenth that of conventional boiler design.

Published accounts of Velox steam generators indicate that steam pressures of about 25 to 35 atmospheres are commonly used, and steam temperatures of 400° to 450° C. (752° to 842° F.). Plants have also been built for lower steam temperatures and pressures.

Additional references in English refer to a Velox installation at an Argentine oil refinery (B.B.C. Item 14), a power station at Wellington, New Zealand (B.B.C. Item 17), and the use of a Velox boiler or Velox blast heater in connection with compressing and heating blast air for iron blast furnaces (B.B.C. Item 5).

## Coal as Fuel for Velox Boilers

Brown, Boveri & Co. have been studying the combustion of coal under pressure for more than 8 years. Development of a Velox boiler for burning pulverized coal under pressure appears to be approaching the point where construction of a full-scale unit for industrial trial should be considered. A gas turbine would be used on the combustion products to provide power for compressing the air for combustion. This development would promise very compact coal-fired power plants, where space is at a premium, high thermal efficiency, quick starting time, flexible automatic regulation, and stack gases free of smoke and fly ash.

Both high-volatile, high-oxygen coking coal from the Saar district and medium-volatile-matter, strongly coking coals from the Ruhr have been used successfully in pilot-plant-scale Velox boiler tests at Baden.

B.B.C. Item 20, pp. 24 and 25, illustrate a projected heating station which

> * * * consists of a Velox steam generator fired with pulverized coal and producing approximately 48 tons of steam per hour.



Generated on 2024-09-19 17:46 GMT / https://hdl.handle.net/2027/osu.32435030643837
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

All of the steam would be used for driving a heat pump by means of a steam turbine. For the arrangement described, the fuel consumption is said to be only 55 to 60 percent that of a low-pressure plant.

> The best possible utilization of the heat content of the fuel is obtained by a Velox steam generator burning pulverized coal, with which more than 90 percent of the available heat in the fuel is utilized, and which can be readily adapted for automatic regualtion of the boiler load.

Two German-language articles published in 1943 on Velox boilers are listed as B.B.C. Items 15 and 16.

Combined Heating and Power Plants

Several of the references cited discuss combination plants to produce both power and heat for space heating or other uses. For example, B.B.C. Item 21 refers to the use of exhaust steam or gases of a power plant for heating purposes. In the case of a steam turbine, the temperature of the exit cooling water would be considerably higher than with a condenser, and the steam pressure at the exhaust of the turbine would also be higher. Such plants are therefore called "back-pressure" plants. Costs are estimated for Swiss conditions.

Applications of the heat pump for centralized heating plants and power plants are discussed in B.B.C. Item 20, pp. 23-26.

Hot-water heating with Velox boilers includes a hot-water system under a pressure of about 12 atmospheres, with an outgoing temperature of about 190° C. (374° F.):

> This type of boiler is frequently used for supplying heat to extensive systems where the heat conveyed is transferred to low-pressure, low-temperature heating systems by means of calorifiers installed in proximity to the consuming centres. (B.B.C. Item 13, p. 20.)

Heat Pumps

A heat pump is a mechanical device that uses power to cause heat to be absorbed at a low temperature level and to be given off at a high temperature level. If used as a refrigerating machine, the useful output of the heat pump is the amount of heat absorbed at the lower temperature (the cooling effect), and the heat evolved at the higher temperature is thrown away. If used as a heating machine, the cooled material is thrown away and the useful output of the heat pump is the amount of heat available at the higher temperature level (the heating effect). This possibility of using the heat pump as a heating machine has long been known to the engineering profession, but only a limited commercial use of the process has been made in the past. Actually, the same machine may be used for cooling in summer and heating in winter.



Generated on 2024-09-19 17:55 GMT / https://hdl.handle.net/2027/osu.32435030643837
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

The principles of the heat pump used both as a refrigerating and heating machine, including the thermodynamic fundamentals, are discussed in B.B.C. Item 20, pp. 1 to 11.

Some applications of the heat pump as a heating machine are discussed in B.B.C. Item 20, pp. 12 to 33. These practical applications refer particularly to Switzerland, where there has been considerable recent development of the heat pump for comfort heating. Usually about two-thirds of the useful heat output is extracted from relatively cold river or lake water, and only one-third is supplied by the electric power required to operate the machine. With some types of space heating, a higher ratio of heat to power can be obtained.

In Switzerland, the object has been to save coal by using hydroelectric power, but it is obvious that the process may be operated with electricity made from coal when convenience, cleanliness, or other reasons lead to the choice of the heat pump process instead of burning the coal directly for heat.

The writer saw the heat pump used on river water to heat the Brown, Boveri plant at Baden. The reference just cited illustrates and describes heat pumps used for:

(a) Producing hot water at 58° to 70° C. (136° to 158° F.) from lake water for an artificial silk plant.

(b) Producing hot air for drying purposes from moist warm air coming from the paper machine of a paper mill.

(c) Producing hot water at 68° to 74° C. (154° to 165° F.) from river water of 2° to 16° C. (36° to 61° F.) to supplement an existing central-heating power plant of the Swiss Federal Institute of Technology at Zurich, which heats a large group of public and private buildings. This heat-pump plant contains two Brown, Boveri thermoblocs. The heating output of the heat pumps is about 15 percent of the total connected-up heating capacity. As a general rule, heat pumps for room heating are dimensioned for a given base load, and peaks are covered by less expensive heat producers, such as fuel-fired boilers.

(d) Air conditioning in one Zurich building is obtained by a heat pump supplying 50,000 kcal/hr. (ca. 200,000 B.t.u./hr.) when heating and 27,000 kcal/hr. (ca. 108,000 B.t.u./hr.) when cooling. B.B.C. supplied part of the equipment.

(e) Evaporation in chemical plants, food-preparation plants, etc., is usually much more favorable to the heat-pump (thermo-compressor) process than room-heating applications, owing to the smaller temperature differentials involved. This permits a higher ratio of useful heat to power consumed and a lower equipment cost per unit of output.

A less technical discussion of applications of the heat pump, with examples, is given by B.B.C. Item 19.



Generated on 2024-09-19 17:54 GMT / https://hdl.handle.net/2027/osu.32435030643837
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

Projected New Thermal Laboratory

Brown, Boveri & Co. expect to erect a new building at Baden for thermal research and testing as soon as the necessary materials of construction are available and conditions permit.

## Conclusions

Brown, Boveri & Co., at Baden, Switzerland, are actively studying the combustion of coal under pressure with respect to the direct use of coal for firing gas turbines and for firing Velox boilers. Engineering tests and design developments now in progress need to be completed before the technical prospects of this work can be evaluated. In a few months the company may feel justified in considering the design of a full-size coal-fired turbine and a coal-fired Velox boiler for trial and further development under industrial conditions.

Of the Swiss firms covered by this report, B.B.C. is the only one that has experimented to date with coal firing of gas turbines. A number of turbines of their design, powered by gas or oil, have already been built.

The oil-fired gas-turbine locomotive built for the Swiss Federal Railways has passed the specified period of test in actual use and has been accepted.

The company has proposed various interesting methods for improving heat economy of metallurgical plants, factories, and central heat and power stations. A separate thermal laboratory building is to be built at Baden when the necessary materials can be obtained.

Brown, Boveri have recently installed heat pumps in Switzerland for space heating, air conditioning, industrial drying and evaporation, etc. A combination of cheap electricity, abundant water supply, and wartime scarcity of imported coal has promoted this development.

## Documents and Publications Referred to in Report I, Brown, Boveri and Co. Ltd.

These documents have been microfilmed on T. O. M. reel 139, original designation SF 6. (Some of the items are reprints from the "Brown, Bovari Review.")

B.B.C. Item 1 (000001 to 000029)

"The Combustion Gas Turbine: Its History, Development, and Prospects," by Adolf Meyer. Paper read at meeting of The Institution of Mechanical Engineers, London, Feb. 24, 1939, and issued in reprint form, with discussion. 26 pp. + 3.

B.B.C. Item 2 (000030 to 000033)

"New Gas Turbines that Work," by S. A. Tucker. Reprint from Power, June 1939. 4 pp.



Generated on 2024-09-19 17:51 GMT / https://hdl.handle.net/2027/osu.32435030643837
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

B.B.C. Item 3 (000034 to 000037)

"Combustion Turbines, Brown, Boveri." 4 pp. 1558E - II. 9 (XII. 39) (1244).

B.B.C. Item 4 (000038 to 000042)

"Load Tests of a Combustion Gas-Turbine Built by Brown, Boveri & Co., Ltd., Baden, Switzerland," by Prof. Dr. A. Stodola. 5 pp. 1584E - II. 9 (VI. 40) (1244).

B.B.C. Item 5 (000043 to 000049)

"New Ways and Means of Compressing and heating Blast Air in Ironworks," by Dr. W. G. Noack. 7 pp. 1787E - IX. 12 (VI. 44) L. 2044.

B.B.C. Item 6a (000050 to 000061)

"Der heutige Stand der Verbrennungsturbine und ihre wirtschaftlichen Aussichten (Today's Position of the Combustion Turbine and Its Economic Outlook)," by Dipl. Ing. Hans Pfenninger. 1 pp + 1. Reprint from Schweiz. Bauzeitung Bd. 123, Nr. 24. u. 26, 10.u.24 Juni, 1944.

B.B.C. Item 6b (not microfilmed)

"A translation of the preceding article, Item 6a, made in the London office of J.I.O.A.-T.I.I.C. Document Center. Copy of this rough translation deposited with L. L. Newman, U. S. Bureau of Mines, Washington, D. C.

B.B.C. Item 7 (000062 to 000069)

"Present-Day Possibilities of the Combustion Turbine," by H. Pfenninger. 8 pp. 1825E - II. 9 (VIII. 44) L. 2044. This is a shorter article than Item 6 and contains fewer illustrations.

B.B.C. Item 8 (000070 to 000081)

"The First Gas-Turbine Locomotive," by Dr. Ing. h. c. Ad. Meyer. 12 pp. 1668E - V. 4 (IX. 42) (L. 2044). (This is a reprint from the Brown, Boveri Rev. 1942, No. 5, pp. 115-126.)

B.B.C. Item 9 (000082 to 000095)

"The Gas-Turbine Locomotive. Specification of the Gas-Turbine Locomotive constructed by Brown, Boveri for the Swiss Federal Railways." July 1945. 14 pp.

B.B.C. Item 10 (000096 to 000121)

"The Rosenkrantzgat Steam Power Station of the Oslo Electricity Works. A Velox Peak-load Plant of Considerable Output," by A. Fischer. Aug. 1937. 26 pp. 1474E - II. 1 (2044).



Generated on 2024-09-19 17:50 GMT / https://hdl.handle.net/2027/osu.32435030643837
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

B.B.C. Item 11 (000122 to 000123)

"The Burning of Gas Under Pressure," by J. G. Coutant. Reprint from American Gas Jour., Feb. 1938, pp. 23-24, 2 pp. N. Y. 110.

B.B.C. Item 12 (000124 to 000134)

"A Modern Stand-By and Peak-Load Steam Power Station Built as a Bomb-Proof Plant," by U. Roth. 9 pp. + 1. 1557E - II. 1. (IX. 39) (2044).

B.B.C. Item 13 (000135 to 000155)

"The Brown, Boveri Velox Steam Generator for Land Purposes." No author stated. 21 pp. 1533E - II. 8 (IX. 40).

B.B.C. Item 14 (000156 to 000162)

"The Velox Power Plant at the San Lorenzo Refinery of the Argentine State Oil Fields," by H. S. Hvistendahl. 7 pp. 1625E - II. 8. (XI. 40) (2044).

B.B.C. Item 15 (000163 to 000178)

"Ein automatisch anfahrendes Velox-Kraftwerk von 10,000 kw. Leistung als Schnellreserve." (An Automatic Process Velox Power Plant for 10,000 kw. Output as Quick Reserve). No author stated. 15 + 1 pp. 1706D - II. 8. (VI. 43) L. 2944.

B.B.C. Item 16 (000179 to 000187)

"Anwendungen des Aufladeverfahrens nach dem Velox-Prinzip" (Application of the Supercharging Process by the Velox Principle), by W. G. Noack. 9 pp. Reprint from Zeitschrift des Vereines deutscher Ingenieure im N.S.B.D.T. Bd. 87 (1943) Nr. 35/36. S. 547 bis 555.

B.B.C. Item 17 (000188 to 000194)

"The Velox Boilers at the Evans Bay Power Station, Wellington, New Zealand," by R. S. Maunder. (No publication reference.) 7 pp.

B.B.C. Item 18 (000195 to 000202)

"Actual Problems in the Production of Power in Thermal Power Station," by Ad. Baumann/W. Broggi. 8 pp. 1553E - II. 1 (VIII. 39).

B.B.C. Item 19 (000203 to 000212)

"Brown, Boveri Heat Pumps for Heating and Cooling. Thermo-compressors for Concentration Plants. You're in a Quandary?." 10 pp. 1673E - IX. 7 (III. 43) L. 2244, K. 16, 17, 18, 21, 34.



Generated on 2024-09-19 17:48 GMT / https://hdl.handle.net/2027/osu.32435030643837
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

B.B.C. Item 20 (000213 to 000246)

"The Heat Pump as Refrigerating and Heating Machine," by A. Meldahl, 11 pp. "Some Applications of the Heat Pump as a Heating Machine," by Ad. Baumann and D. Marples. 22 pp. Total 33 + 1 pp. 1747E - XI. 7. (XII. 43) L. 2044.

B.B.C. Item 21 (000247 to 000259)

"Thermische Anlagen für Reserve-, Erganzungs- und Heizkraftworke mit besonderer Berücksichtigung der Turbine." PP. 69-78. "Centrales thermiques de reserve, centrales auxiliaires et centrales chauffage-force matrice." PP. 78-79. "Caloric power plants as emergency, supplementary and combined heating and power plants." PP. 79-80. By P. Faber. Article in German with 2/3 page abstracts in French and English. From magazine Elektrizitäts Verwertung - L'Electrique - Electrical Service. 20th year, No. 1-3, pp. 69-80. 12 + 1 pp.

## REPORT II. - ESCHER WYSS ENGINEERING WORKS, LTD.

### Location of Target

The office and factory of Escher Wyss Engineering Works, Ltd., are in Zurich, Switzerland, at Escher Wyss Platz.

### Date of Investigation

The investigation was made on September 21 and 22, 1945.

### General Information and Personnel Met

The following persons were met:

Dr. Eng. C. Keller, chief engineer of the Research Dept. (Equivalent in U. S. to Director of Research and Development.)

E. J. Meier, mechanical engineer of the A. K. Dept. (Manager of the thermal section and formerly chief designer for turbines.)

### Information Obtained on Products

Early Water and Steam Turbines

Escher Wyss have published "A Century of Turbines," which is the combined 1942/43 volumes of Escher Wyss News. (See EW Item 1a, in list of documents and publications at the end of the Escher Wyss part of this report. These documents have been microfilmed on T.O.M. reel 139, original designation SF 6.)

The business of Escher Wyss is built around turbines of all types, and the history of this company in turbine construction since 1840 is summarized



Generated on 2024-09-19 17:51 GMT / https://hdl.handle.net/2027/osu.32435030643837
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

in EW, Item 1b. (See also EW Item 2c (microfilm 000307-8) for a list of their publications on turbine research.)

Aerodynamic Turbine

Escher Wyss have developed a gas turbine which they call an "aerodynamic turbine with closed circuit," the principles of which are discussed in an article of that title by Prof. Dr. J. Ackeret and Dr. C. Keller (EW Item 1c). It is compared with steam and gas turbines in an article by Dr. Keller (EW Item 1d).

The working fluid is air, which circulates in a closed cycle under pressure, thus permitting smaller parts because of the denser working medium. The thermal efficiency is independent of the absolute pressures, and the choice of pressure level is determined by considerations of design. It is said that maximum pressures of 20 to 30 atmospheres represent satisfactory figures for even the largest unit outputs. The best ratio of inlet to outlet pressures is about four, as in open-cycle turbines. One of the advantages claimed for this system is the ability to control the output without much effect on thermal efficiency by simply changing the pressure level of the air in the system. This changes the weight of the circulating medium without affecting temperatures or velocities.

The recirculated air is compressed by axial-flow compressors with water intercoolers (which require one-tenth to one-fifth as much cooling water as a steam turbine plant). The high-pressure air is then heated:

(a) In a heat exchanger by hot air from the turbine exhaust.

(b) In a fuel-fired heater, in which the furnace chamber may be maintained at atmospheric pressure.

For other general references to this type of turbine, see EW Items 2b and 8.

The writer saw the development model 2,000-kw. aerodynamic turbine which has been built and tested at the Escher Wyss plant. Construction was begun in 1936, and the turbine was first operated in 1939.

Turbine Performance Tests

Official performance tests were made in December 1944 by Prof. H. Quiby of the Federal Polytechnic School at Zurich, and are described in a French-language article filed with this report (EW Item 4). A two-page summary in English (EW Item 5) has recently become available to American readers, so that an extensive summary is not required in this report.

In these tests, heated air at 1,268° F. to 1,288° F. and at 343 to 83.8 lb. pressure (depending on the desired load) was passed through the high-pressure turbine that drove the compressor (consuming about 60 percent of



Generated on 2024-09-19 17:46 GMT / https://hdl.handle.net/2027/osu.32435030643837
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

the output), then to the low-pressure turbine that drove the generator (consuming about 40 percent of the output). Exhaust air from the turbine had temperatures of 829° to 846° F., and the ratio of turbine inlet to outlet air pressure was about 3.56:1 in each case. The net thermal efficiency, after allowing for all losses, was 31.5 percent at 2,044 kw. output, 29.6 percent at half load, and 24.5 percent at one-fifth load, when figured on the net heating value of the fuel, in accordance with European practice. (Thermal efficiencies would be somewhat lower if calculated on the gross heating value of the oil, as in American practice). Very cold cooling water was doubtless available in these December tests.

Solid Fuel and Derived Gaseous Fuels For Turbines

The closed-cycle turbine has not been tested with solid or gaseous fuels as yet, but Escher Wyss publications contain the following statements regarding the use of solid fuel or gas derived from solid fuel:

> Employment of gaseous and solid fuels. For the employment of gaseous fuels in open-circuit gas-turbine plants with internal combustion, it is necessary to cool and sometimes purify same before the compression phase. In the case of closed-circuit installations with external firing, such cooling of the fuel is unnecessary; a separate gas compressor is eliminated, whilst the sensitivity of the plant to any solid matter in the fuel is, of course, also reduced. A much more difficult matter is the use of solid fuel, i.e., chiefly pulverized coal, in gas turbines designed for internal combustion, since soiling and wear both of the turbine and heat exchanger have to be dealt with. On the other hand, the external combustion of pulverized coal, although presenting certain complications compared with oil firing, is much easier to realize, since similar experience in ordinary steam boiler plants is available. If it is possible to employ pulverized coal for the operation of aerodynamic turbines with the efficiencies later referred to an exceptionally economical power plant for large outputs will be available. The gasification of solid fuels in suitable gas producers followed by combustion of the gas in air heaters might also be considered. (EW Item 1c, p. 13.)

Producer gas fuel is also referred to as follows:

> When coal is employed as fuel it may, according to the nature and quality of the coal, prove convenient to adopt gas generators in place of furnaces for producing the combustion gases for the air heater. In this connection, no cleaning, cooling down, or compression is necessary such as are called for when an open cycle is adopted. The operation of up-to-date gas generators also makes adaptation and control of the heating an easy matter. (EW Item 1d, p. 40.)

The same reference, in discussing the air heater, mentions pulverized coal firing:



Generated on 2024-09-19 17:48 GMT / https://hdl.handle.net/2027/osu.32435030643837
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

> Careful calculation of all these problems has led to a series of fundamental circulation lay-outs for the working medium to be heated and for the heating combustion gases. They permit, for a minimum loss of pressure and without the adoption of special measures, the attainment with all fuels, i.e., solid, liquid, and gaseous, of maximum air temperatures lying far above those of the steam temperatures now employed or which it is hoped to employ in the future. In view of the fact that the waste gases from the air heater have relatively high temperatures, their waste heat can be employed advantageously for preheating the combustion air. The use of preheated combustion air leads to an increase in the furnace temperature, particularly in cases where solid fuels (coal) are used. For example, in plants burning pulverized coal such preheating of the secondary air is very desirable, since it permits a reduction in the size of the furnace as a consequence of the shorter combustion period. On the other hand, the duty to which the tubes are subjected is more exacting where higher furnace temperatures are adopted. A simple means for compensating these conditions is a return circuit of the flue gases to the combustion chamber, whereby practically any desired temperature in this chamber can be adhered to. (EW Item 1d, pp. 30, 31.) See EW Item 5, p. 2, for arrangement of an air heater for pulverized-coal firing with recycled flue gas.

Curves are shown that illustrate the advantage of the closed cycle with recirculated air under pressure for keeping down the temperature of the air-heater tubes. Figure 38 (p. 37) of EW Item 1d compares the cost of fuel at power stations when using various fuels and types of equipment. The legend states, in part, "Unlike open-circuit gas turbines and Diesel engines, aerodynamic plants can be operated with coal." The thermal efficiency for thermodynamic turbines fired with coal is assumed to be 35 percent, with a footnote indicating that this 35 percent is a

> Possible figure in large installations after a future period of development. In contradistinction to other thermal prime movers, a considerable margin for further increases in efficiency exists in this case.

The use of waste gases from various industries is discussed in EW Item 1d, pp. 39-40. This calls attention to the large dimensions of other equipment to use such waste gases and points out the advantage of using the gases as fuel for the air heater of an aerodynamic turbine. It discusses the use of such a turbine, fired with blast-furnace gas, to drive blast-furnace blowers, which must operate under widely different speeds and loads. See, also, a German-language article (EW Item 3) on the applications of aerodynamic turbines in metallurgical plants.

Availability of Aerodynamic Turbines

The only turbine of this type that has yet been constructed is the 2,000-kw. development model at the Escher Wyss plant. Subject to establishing a satisfactory source of supply of alloy-metal tubes for the air heaters, the



Generated on 2024-09-19 17:53 GMT / https://hdl.handle.net/2027/osu.32435030643837
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

company is ready to accept commercial orders for oil-fired stationary or marine aerodynamic turbines in three sizes, namely, 6,000, 12,000 and 25,000 kw. Still larger units are envisioned for future plants, according to EW Item 1d, p. 36-37, which suggests single-shaft outputs of 100,000 kw. with maximum pressures not over 30 atmospheres. Presumably, the company would accept orders for producer-gas-fired or blast-furnace-gas-fired turbines, also. Preliminary studies on application to locomotives are being made. In the case of coal-fired installations, the company would wish to collaborate with an engineering firm experienced in the combustion of coal.

Combined Heating and Power Plants

It is pointed out (EW Item 1d, pp. 40-41) that the cooling water from the pre-cooler and compressor intercoolers can be allowed to rise to 80° C. (176° F.) or more, without altering the temperatures in the circuit or changing the work output of the aerodynamic turbine plant. This water can be distributed as hot-water supply or for distant heating without the necessity of returning the water. Figure 4 of EW Item 5 indicates that in a test about 46 percent of the total heat in the fuel burned was removed in the cooling water. (In a steam-turbine plant, the necessity of maintaining a good vacuum usually results in the use of very large volumes of cooling water, which may be raised only a few degrees and therefore is not directly suitable for hot-water supply or for heating purposes.)

Heat Pumps

The use of electrically driven "heat pumps" for heating or refrigerating has been briefly discussed in Part I of this report. Both of these applications are covered by an Escher Wyss publication (EW Items 6a, b, and c). Item 6c is an article on "Heating Systems With Heat Pumps" by A. Astertag, which includes considerable technical information.

The yield of the heat pump is greatest when the temperature difference between the source of heat and the material to be heated is least. It is therefore well suited for radiation or "panel" heating of the type in which the heating pipes are embedded in the ceiling or other room surfaces and the circulated water is not as hot as that used in conventional radiators.

Owing to the high initial cost of heat pumps and the highly variable daily heat requirements for comfort heating, it is considered preferable to design the heat pumps for the base heating load and to use a supplementary heating system for occasional peak-load demands, which form only a small percent of the total annual heat needed. An engineering study is required to determine whether this is a practical solution in specific cases. See examples in the text, based upon Swiss weather and for various heating problems, such as:

(a) The Zurich town hall, where the same heat pump, operating on river water, serves for heating in winter and cooling in summer. Heating-water storage tanks are provided for peak periods of heating. (See figs. 10 to 13, p. 36.)



Generated on 2024-09-19 17:51 GMT / https://hdl.handle.net/2027/osu.32435030643837
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

(b) The Zurich public baths, where heat pumps heat the swimming bath water, showers, and ventilating air and provide radiation comfort heating.

The Lausanne artificial-ice rink uses heat from the refrigerating plant to raise the temperature of the entire city water supply by 2.5° C. (4.5° F.), thus economizing on the heating of water for cooking, washing, and bathing.

Another publication (EW 7a and b), in the German language, contains additional technical information and examples of heat-pump applications.

It has already been mentioned in Part I of this report that a special combination of circumstances has led to the adoption of heat-pumps for various cases of comfort heating in Switzerland. Such favorable conditions might represent only a small percentage of cases in much of the area of the United States.

In the past, Escher Wyss made numerous installations of heat pumps for industrial evaporating purposes in Switzerland and elsewhere. It is said that the largest heat pump in the world is an Escher Wyss plant that evaporates 220,000 lb/hr. of water with a total power consumption of only 4,000 kw.

## Research Activities

Escher Wyss has issued a publication, Research on Turbo machinery (EW Item 2a), the 19 articles of which are listed on the index page (microfilm p. 000302). Only one of these refers specifically to aerodynamic turbines (EW Item 2b). Publications of research work on Escher Wyss turbines of all types are listed at the end of the reference (EW Item 2c, microfilm pp. 000307-8).

It is said that this company has, for several years, maintained about 25 graduate engineers on development research. One effect of the war upon the neutral Swiss was to give them time to perfect their ideas and designs for aerodynamic turbines for stationary and marine applications.

## Conclusions

The Escher Wyss Engineering Works, Ltd., has developed an "aerodynamic" gas turbine in which the working fluid is air circulated under pressure. Because of the denser medium, the working parts are smaller, and units may be built in larger capacities than with open-circuit gas turbines. Outputs may be varied without much change in thermal efficiency by varying the pressure level in the system. A variety of fuels may be used, with combustion at atmospheric pressure, as the combustion gases do not pass through the turbine but serve to heat the recirculating air, which is passed through tubes in the air heater and heat exchanger. Cooling-water requirements are about one-fifth to one-tenth those of a steam-turbine power plant.

The only turbine of this design that has been built to date is the 2,000 kw. development unit at the Escher Wyss plant. With inlet air at about



Generated on 2024-09-19 17:45 GMT / https://hdl.handle.net/2027/osu.32435030643837
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

1,275° F., the net thermal efficiency after allowing for all losses was about 30 to 31.5 percent from half load to full load. (These efficiencies were based on the net calorific value of the oil used, and the cooling water was evidently very cold during the test).

Subject to obtaining a satisfactory source of supply for alloy air-heater tubes, Escher Wyss is prepared to accept orders for oil-fired (and presumably gas-fired) aerodynamic turbines for stationary or marine use in 6,000, 12,000-, and 25,000-kw. sizes. They have not yet tried pulverized coal or producer gas as fuel, but refer to both in their publications. Stationary power units of still larger size, fired with coal with a thermal efficiency of 35 percent or more, are mentioned as a possibility after a future period of development.

The cooling water may be drawn off at around 175° F. (without affecting turbine performance or output) and used as hot-water supply or for heating purposes.

Escher Wyss has made many heat-pump installations for industrial evaporation, and more recently have built heat pumps for comfort heating and air-conditioning (winter heating and summer cooling).

Documents and Publications Referred to in Report II - Escher Wyss Engineering Works, Lts.

(These documents have been microfilmed on T.O.M. reel 139, original designation SF 6, pp. 000260 to 000382 and 000761 to 000771.) (Some of the items are reprints from Escher Wyss News.)

EW Item 1a (microfilm pages CC0260 to 000261).

Cover page and index of "A Century of Turbines." Escher Wyss News, vol. XV/XVI, 1942/43. Pp. 1 and 2. 2 pp.

EW Item 1b (000262 to 000263)

"A Century of Turbines." A summary with dates, of Escher Wyss work in turbine construction, beginning with 1840. Pp. 3 and 4. 2 pp.

EW Item 1c (000264 to 000278)

"Aerodynamic Turbine with Closed Circuit." By Prof. Dr. J. Ackeret and Dr. C. Keller. Pp. 5 to 19. 15 pp.

EW Item 1d (000279 to 000300)

"The Aerodynamic Turbine Compared with Steam- and Gas-Turbines." By Dr. C. Keller. Pp. 20 to 41. 22 pp.

EW Item 2a (000301) to 000302)

Cover page and index of "Escher Wyss Research on Turbo-machinery." 23001 (e). 2 pp.



Generated on 2024-09-19 17:44 GMT / https://hdl.handle.net/2027/osu.32435030643837
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

EW Item 2b (000303 to 000306)

"An Aerodynamic Heat-Power Plant." By Prof. Dr. J. Ackeret and chief engineer Dr. C. Keller. Pp. 82-85. 4 pp. Also published in "Schweizerische Bauzeitung", Vol. 113, no. 19, May 1939.

EW Item 2c (000307 to 000308)

List of "Publications of Research Work for Escher Wyss Designs" of turbines. Inside back cover. 2 pp.

EW Item 3 (000309 to 000315)

"Die Aerodynamische Turbine im Hüttenwerk" (The Aerodynamic Turbine in Metallurgical Plants). By Dr. sc. techn. C. Keller and Dipl. Ing. R. Ruegg. Reprint from "Schweiz. Bauzeitung". Bd. 122, Nr. 1, 3 July, 1943. 7 pp. 23012 (d).

EW Item 4 (000316 to 000344)

"Compte-rendu des essais de la turbine aérodynamique Escher Wyss AK" ("Account of trials of the Aerodynamic Turbine Escher Wyss AK"). By Prof. H. Quiby. Reprint from vol. 125, Nos. 23 and 24, 9/16 June 1945. 28 + 1 pp. No. 23021.

EW Item 5 (000345 to 000346)

"Performance Tests of 2000-kw. Closed-Cycle Unit." Power, Aug. 1945. 2 pp. A summary in English of EW - Item 4.

EW Item 6a (000347 to 000348)

Cover page and index of "Escher Wyss Refrigerating Machines: Heat Pumps." 2 pp. 24006 (e).

EW Item 6b (000349)

"Heat Pumps." P. 31. 1 p.

EW Item 6c (000350 to 000364)

"Heating systems with heat pumps," by A. Ostertag. pp. 32-46. 15 pp.

EW Item 7a (000365 to 000366)

Cover and contents page of "Escher Wyss Kälte-Wärme" (Cold-Heat). 2 pp 24010 (d).

EW Item 7b (000367 to 000382)

"Die Wärmepumpe in der Heiztechnik" (Heat Pumps in Heating Technique). By A. Ostertag and A. Kornfehl. pp. 25-40. 16 pp.



Generated on 2024-09-19 17:48 GMT / https://hdl.handle.net/2027/osu.32435030643837
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

EW Item 8 (000761 to 000771)

"Die Aerodynamische Turbine 'Escher Wyss AK' - Anlassee: L'installation de turbine aérodynamique 'Escher Wyss': The 'Escher Wyss AK' aerodynamic turbine power plant" by Dr. C. Keller. A German-language article with half-page summaries and titles to figures in French and English. "Elektrizitäts-verwertung - L'Electrique - Electrical Service." 20th year, Nos. 1-3, April-June 1945, pp. 81-91, 12 pp.

REPORT III. - SULZER BROS., LTD.

Location of Target

The office and factory of Sulzer Bros. Ltd. are at Winterthur, about 15 miles northeast of Zurich, Switzerland. The plant is adjacent to and northwest of the railway station.

Date of Investigation

The investigation was made on September 26 and 27, 1945.

General Information and Personnel Met

The following persons were met:

Dr. Frederick Oederlin, managing director (of engineering).

Dr. Herbert Walfer, director of research.

Adolf Egli, in charge of gas-turbine department.

Max E. Trechsel, in charge of public relations, patents, etc.

Dir. J. Gastpar, manager of boiler department.

Mr. Vogler, chief engineer of boiler department.

Viktor Juzi, chief engineer for high-pressure boiler plants.

F. Eicher, engineer, boiler sales department.

Mr. Felber, manager of comfort-heating equipment, etc.

Mr. Wirth, chief engineer of comfort-heating equipment, etc.

Adolf Brunner, in charge of locomotive department.

Information Obtained on Products

Sulzer Bros. make a considerable variety of products, such as Diesel engines, pumps, fans and compressors, steam boilers, steam engines and



Generated on 2024-09-19 17:47 GMT / https://hdl.handle.net/2027/osu.32435030643837
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

turbines, heating and ventilating plants, refrigerating plants, sheet-metal and foundry work, etc. An illustrated summary of products is given in Sulzer - Item 19. See list of Documents and Publications at the end of this report. These documents have been microfilmed on T.O.M. reel 139, original designation SF 6. Numerous examples of boiler and plate work are given in Sulzer - Item 18.

Heat-Engine Developments

Past activities of Sulzer Bros. in the power field have been mostly concerned with Diesel engines, boilers, and steam engines. A special number of the Sulzer Technical Review, dated December 31, 1941 (Sulzer Item 1), is entitled The Supercharging of Two-stroke Diesel Engines. It refers to:

(a) Supercharged two-stroke Diesel engines with exhaust-gas turbines.

(b) "Power-gas" Diesel engines in which the engine-compressor unit delivers no mechanical energy but serves exclusively to supply exhaust or power gas to a gas turbine.

(c) Sulzer development work on a constant-pressure gas turbine of their own system as a thermal prime mover (no details given).

Sulzer Bros. kindly gave the writer a copy of a typed memo New Sulzer Designs in the Domain of the Heat Engine, which it was said was to be released shortly to the technical press as a progress report (Sulzer Item 2). It summarizes recent developments on the above and other items.

Constant-Pressure Combustion Turbine

Very little information has been released on the Sulzer gas turbine. The previous reference states (pp. 3-4):

> The special feature of the Sulzer gas turbine consists in the employment of a new type of circuit, which retains the essential advantages of the known closed circuit without having its main disadvantage in the form of a large and heavy air-heating chamber. The Sulzer air heater used instead is considerably smaller and lighter, which makes the plant particularly interesting for marine propulsion. The thermal efficiency exceeds that of the best marine steam turbines even at small powers, and with full utilization of all present advantages and inherent possibilities will be raised very near that of the Diesel engine.
>
> The trial plant of a marine turbine on this new system, to give an effective output of 7,000 S.H.P., is at present under construction.

In the present stage of development, Sulzer Bros. have been considering oil-fired gas turbines especially for marine use. However, these turbines



Generated on 2024-09-19 17:44 GMT / https://hdl.handle.net/2027/osu.32435030643837
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

could also be used for stationary power plants, and probably could be adapted to locomotive use. Not much consideration has been given as yet to the possibility of firing direct with coal. However, this could be done whenever coal-combustion and turbine-blade technology reach the point where coal can be burned under considerable pressure to yield hot combustion products clean enough to pass directly through a turbine. Firing with pressure-producer gas is another possibility.

Monotube High-Pressure Steam Generators

Information was obtained on recent developments of the Sulzer monotube high-pressure boiler. A list of these steam generators was obtained (Sulzer Item 16), which shows a total of 51 units built or under construction in Switzerland, Great Britain, France, Holland, Germany, Italy, Hungary, and Roumania. Forty-two of these use solid fuel, of which 26 are fired with pulverized coal, 13 with traveling grates, and one each with underfeed stoker, mechanical overfeed stoker, and with coke. One is fired with blast-furnace gas, seven with oil, and in one case the firing method is not specified. Brief information on rating, steam temperature and pressure, and auxiliaries is given for each plant.

As this type of steam generator was known a few years before the war, it is not necessary to describe it in detail here. For convenient reference, several of the earlier publications have been included in the documents filed with this report. (See Sulzer Items 3, 5, 7.) Also included is a copy of a typed report, dated 1936 (Sulzer Item 4), on a power plant of this type for a colliery in Wales. This describes a complete high-pressure, back-pressure plant with two monotube steam generators that work in conjunction with an existing plant having medium pressures. Each monotube generator produces 50 or more tons of steam per hour (at 110 atm. gage and 770° F.) on the same floor space formerly used to generate 16 tons per hour (at 25 atm. gage and 762° F.). Pulverized-coal firing is used. Sulzer Item 6 is a mimeographed general description of the monotube steam generator, dated 1937.

Sulzer recommends this type of high-pressure steam generator for pressures over 80 atmospheres. Each unit tube is capable of producing about 10 tons of steam per hour and consists of a continuous welded tube several thousand feet long, in which the feed water is preheated and evaporated and the resulting steam is superheated. This tube is bent to form banks of preheater and superheater tubes as well as furnace walls. For larger capacities, several of the unit tubes are used and bent to lie parallel. There is automatic regulation of feed water, pressure, and temperature of superheated steam, and prompt synchronization of heat input and removal under varying load conditions. It is said that there has been considerable improvement and simplification of the controls.

At the end of the zone of evaporation there is a continuous blow-down device to maintain the concentration of salts within certain limits. A report on measurements of the salt content at various points in the circuit is given in Sulzer - Item 14. It was concluded that adequately pure steam



Generated on 2024-09-19 17:52 GMT / https://hdl.handle.net/2027/osu.32435030643837
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

(8 to 10 mg. per liter residue on evaporation, or 0.47 to 0.58 grain/gal.) could be obtained, even though the blow-down device was discharging water of 500 mg./l. residue (29.2 grains/gal.) and the make-up condensate was impure, containing 150 mg./l. of residue (8.8 grains/gal.).

An interesting high-pressure steam plant in an English carboard factory is described in Sulzer - Item 8. The steam generator and turbines of this coal-fired plant are all in the same room. Coal is brought by Redler conveyors direct from the coal-storage yard to the hoppers on traveling-grate stokers. The space below the grates is hermetically sealed off from the boiler and engine room to prevent the escape of dust. The combustion gases pass through a van Tongeren dust collector of Sulzer design before being discharged to the atmosphere. Three generators, each with a capacity of 37 tons/hr. of steam at 100 atmospheres and 797° F., were installed. An 8-hour test on one of these, when raising about 30 tons/hr. of steam, showed 89 percent efficiency.

Drawings and photographs of a number of monotube steam generators are contained in Sulzer - Item 10. These show sectional views and plant arrangements as well as detailed views of various elements and accessories for this system. Plant lay-outs and furnace-wall details are shown for both powdered coal and chain-grate-stoker firing. A photograph is shown of a Sulzer van Tongeren dust separator on a boiler-house roof. For additional illustrations of boilers and accessories, see Sulzer Items 18 and 19.

A well-illustrated 16-page publication in the German language, accompanied by a typed Sulzer translation of the text and titles of figures, makes up Sulzer Items 12a and 12b. Item 13 is a 4-page descriptive leaflet in English.

The most recent published article is one dated 1945 by Director Gaspar (Sulzer Item 9f). The text is in the German language, but each figure has English and French titles, and there is also a half-page summary of the article in each of these languages. The title is "Planning boiler and accumulator plants for industrial power stations, with special reference to back-pressure energy production." A large drawing of a diagram of a high-pressure steam plant with reheater is filed as Sulzer Item 11. It is similar to figure 32 on page 52 of Sulzer Item 9f.

The latest reference on this topic is a typed memorandum that was prepared for the writer on September 27, 1945, entitled "High-pressure installations equipped with Sulzer monotube steam boilers." (Sulzer Item 15.) It states, in part:

> Most of the land installations have been built as superimposed high-pressure plants to existing steam-generating equipment. The existing installations contained obsolete equipment running with a low over-all plant efficiency, and the purpose of the superimposing of the high-pressure plant was, besides obtaining a larger output of electric power, to reduce the coal consumption.



Generated on 2024-09-19 17:45 GMT / https://hdl.handle.net/2027/osu.32435030643837
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

> The Sulzer monotube steam boilers are best suited for pressures above 80 atm., and the highest pressure up to now in service is 140 atm., although from the point of view of design and construction of the monotube boiler there is practically no upper limit. The steam temperature at superheater outlet used in most of the now (sic.) installations is in the neighbourhood of 500° C. (932° F.). Sulzer Bros. have on hand designs for monotube boilers working with steam temperatures up to 600° C. (1,112° F.), and these can be put on the market as soon as the special material for the superheater portion of the boilers is available.

This statement is followed by a discussion of improvement in plant efficiency in some cases by reheating the exhaust steam from high-pressure turbines. This can be done by a separate oil or gas-fired unit, but the Sulzer monotube generator is said to permit cheaper and more efficient heating up to about 20 atmospheres and 750° F. by incorporating the reheater in the boiler itself.

The preheating of feedwater in several stages is another means of improving plant efficiency, which can be incorporated in Sulzer high-pressure installations:

> The number of stages for the preheating and its final temperature depends on the type of firing equipment, as it is bound up with the admissable air heating. With stoker-fired boilers where an air temperature of about 120° C. (248° F.) is generally adopted, the feedwater is preheated up to about 150° C. (302° F.); for boilers with pulverized-coal firing, the air preheating can go as high as 300° or even 400° C. (572° to 752° F.), and the feed heating accordingly reaches about 200° C. (392° F.), for which usually four stages are provided.

The use of high-ash or high-moisture fuels is discussed as follows:

> The monotube boiler is suitable for burning practically any type of fuel. Particularly in the past years, where the good coal has been used for other purposes, we have been compelled to build boilers for burning coals with ash and water contents up to 40 to 50%. No particular difficulties have been experienced in this respect with the monotube boilers built for coals of such low quality, and Sulzer Bros. see no objection in using coals with even higher ash and water contents than those mentioned above. Furthermore, the monotube boiler can easily be adapted to any firing equipment, be it stokers or pulverized-firing installations. As regards the pulverized-coal firing, however, Sulzer Bros. have adopted in most cases the tangential firing with the burners arranged in the corners, the system as developed by the Combustion Engineering Company. In order to avoid slag deposits on the tubes lining the combustion chamber or a choking up of the entire boiler, which may occur at high outputs when using coal, the ashes of which



Generated on 2024-09-19 17:47 GMT / https://hdl.handle.net/2027/osu.32435030643837
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

have a low melting point, the first tube bundle at the outlet of the combustion chamber is usually provided with a wide tube spacing. With the design of the combustion chamber as adopted by Sulzer Bros. there are no difficulties in choosing a low figure for the heat release in the combustion chamber (B.t.u./c.-ft) which is particularly necessary when using coal of low quality.

The concluding statement is:

> With a new large size plant working with 160 atm. 600° C. (1,112° F.) and reheat to 600° C. (1,112° F.), it will be possible to attain over-all plant efficiencies of up to 36 percent, provided all components of the plant are properly designed.

It is stated in Item 2. p. 5, that:

> Steam power plants of this type offer efficiencies such as are expected from the known forms of gas-turbine plant, and they are also quite able to compete with the latter in the matter of space requirements.

Combined Heating and Power Plants

Sulzer Item 12b, p. 2, discusses the advantages of using high-pressure steam first for power and then as low-pressure steam for industrial process work or heating:

> It offers a particularly favorable solution for industrial concerns which need both power and heating steam in large quantities. The high-pressure steam then supplied by it can first generate power while being expanded to a suitable back pressure in a power unit, and afterwards can be used as heating steam, either directly or by the employment of a steam transformer. The energy thus obtained is a by-product and is accordingly cheaper than power generated by any other thermal means.

Sulzer Bros. consider the design and construction of such plants, including the superimposing of high-pressure plants on existing medium- or low-pressure steam plants, to be one of their specialities. (Sulzer Item 2, p. 5.)

Items 7 and 8 describe two coal-fired plants in which steam at 100 atmospheres is first used for power and then as relatively low-pressure process steam in a cardboard factory and a bobbin and spool works.

There is an extended discussion of various aspects of simultaneous heat and power production in Sulzer Item 9f.



Generated on 2024-09-19 17:48 GMT / https://hdl.handle.net/2027/osu.32435030643837
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

O. Walti, in a paper entitled "The Past and Future of the Steam Engine" (Sulzer Item 17e), states that the economic position of the steam engine is being restored by the use of high-pressure steam in engines for power followed by use of the steam for process work and heating.

H. Nyffenegger discusses "Combined Heating and Power Plants with Back-pressure Piston-type Steam Engine" in a German-language article accompanied by a half-page English summary and English titles to the figures.

Heat Pumps

Sulzer Bros. have for years manufactured evaporating plants for the chemical and food industries. The economy of such evaporating (concentrating) plants, with and without heat pumps, is discussed in Item 17d by W. Wittwer. Among the factors that favor heat pumps are high fuel cost and a good load factor. The heat-pump plant has low cooling-water consumption. For an evaporator with contents boiling at about 212° F., as much as 44 to 55 pounds of water can be evaporated per kw.-hr. of electric power supplied to the heat pump.

"Centrifugal Pumps in Heat Pump Plants," by J. Sprecher, is the title of Item 17c. Sulzer centrifugal pumps have been used to deliver water to a number of heat-pump plants, including some described in Part I of this report, in which Brown, Boveri & Co. "thermoblocs" were installed.

The use of an oil-free reciprocating compressor as a heat pump in concentrating plants, where the vapors must not be contaminated by lubricating oil, is described in Sulzer Item 17b.

Radiation Heating from Ceilings

Three publications were obtained, all in the German language, on comfort heating, air conditioning, etc. (Sulzer Items 21, 22, 23). These contain very little detailed technical information. Item 21 describes the advantage of radiation heating and cooling from ceilings containing pipe coils. It contains many general views of public, industrial, and private dwellings that have radiation heating by the "System Crittall." Page 16 shows an exterior view of the newly built (1942-43) city hospital of Basel, Switzerland, which has 81 miles of pipe coil. This is said to be the largest radiation heating installation on the Continent, and it also provides cooling of the bed area in summer. Item 22 gives the names and addresses of nearly 100 of these installations, with length of concreted heating spiral. These include hospitals, office buildings, indoor swimming pools, schoolhouses, museums, dwellings, etc.

Item 23 contains many small photographs of buildings with Sulzer installations of central heating, air conditioning, distant heating, ventilating, etc.

In industrial plants, water may be heated up to 180° C. (357° F.) by waste steam and circulated under pressure to radiators for heating purposes.



Generated on 2024-09-19 17:48 GMT / https://hdl.handle.net/2027/osu.32435030643837
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

## Research Laboratories

Sulzer Bros. recently completed a large new laboratory building for research, development, and control work. A recent issue of the company's Technical Review is devoted to this building. (Sulzer Item 20a.) Floor plans and some of the major equipment are shown in Item 20d. The oscillographic equipment of the new physical laboratory is described in Item 20c. Of interest in connection with gas turbines is their investigation of "Brittleness and Toughness of Metals at High Temperatures" (Item 20b).

Adjoining existing buildings house the thermal laboratory and aerodynamic laboratory. From an inspection of the various laboratories, it is evident that this company has excellent facilities for engineering research and control work in their field.

## Conclusions

Sulzer Bros. have investigated gas turbines powered by exhaust gases from Diesel engines, also constant-pressure combustion turbines as prime movers. They are constructing a 7,000 S.H.P. oil-fired marine combustion turbine with their own type of circuit for trial purposes.

Little information has been released on the Sulzer combustion turbine. It is claimed to have certain advantages of a closed circuit without the necessity of a large air-heating chamber. They have not yet given much consideration to the use of coal as gas-turbine fuel.

About 50 monotube, high-pressure, steam-generator units (mostly coal-fired) have been built in eight European countries. They recommend these for pressures over 80 atmospheres. Most of the present plants superheat the steam to about 500° C. (932° F.) and the present maximum working pressure is 140 atmospheres. However, as soon as known alloys are commercially available, they are prepared to build generators producing steam at 160 atmospheres and 600° C. (1,112° F.), with an expected over-all plant efficiency up to 36 percent. Most of the present installations have been built as superimposed high-pressure plants to supplement existing medium- or low-pressure steam plants.

Much attention has been given to increasing fuel economy through combined heating and power installations in which high-pressure steam is used in back-pressure steam turbines or steam engines and the exhaust steam is used for heating or process purposes.

Sulzer Bros. manufacture plants for industrial evaporation and have supplied centrifugal pumps and other accessories to recent installations of "heat pumps" for comfort heating.

They have an extensive business in central heating, air-conditioning, ventilating, etc., and have made many large installations of comfort heating and cooling by coils embedded in ceilings ("System Crittall").



Generated on 2024-09-19 17:51 GMT / https://hdl.handle.net/2027/osu.32435030643837
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

They have just completed a large and admirably equipped laboratory for metallurgical, physical, and chemical work. In combination with their existing thermal and aerodynamic laboratories, this gives them excellent facilities for engineering research, development and control work in their field.

## Present Swiss Views on Energy Problems

A recent issue of the Swiss magazine "Electrical Service" is devoted to articles on the more effective use of energy sources. They believe that in Europe the demand for fuels and electricity will exceed the supply for some time to come.

Some of the articles in this issue have already been cited. Three general articles on energy problems, especially water power and coal, are mentioned in closing this report, as they will help to explain the viewpoints and policies of Swiss development engineers.

For convenience in microfilming, these items have been listed with the Sulzer publications. For the cover page and contents page see Sulzer Items 9a and 9b. The articles are in the German language, with half-page summaries in English and French.

The three articles of general interest are:

"Water Power and Coal" - and editorial (item 9c).

"Energy as seen by Modern Science," by Prof. Dr. Franz Tank, rector of the Federal Polytechnic School, Zurich (item 9d).

"Meeting the Demand for Energy by means of Water Power," by Prof. Dr. Bruno Bauer, Federal Polytechnic School, Zurich (item 9c).

A continuing shortage of imported coal has led to the exploitation of Swiss peat deposits, and the writer saw peat being tested as boiler fuel.

## Documents and Publications Referred to in Report III - Sulzer Bros., Ltd.

These documents have been microfilmed on T.O.M. reel 139, original designation SF 6, pp.000383 to 000760, and 00772 to 00814. (Some of the items are reprints from "Technical Review Sulzer").

### Sulzer Item 1 (000383 to 000406)

"The Supercharging of Two-Stroke Diesel Engines." Special number of the Technical Review Sulzer. Dec. 31, 1941. 21 + 3 pp.

### Sulzer Item 2 (000407 to 000412)

"New Sulzer designs in the domain of the heat engine". Typed memo, undated, obtained September 27, 1945. 6 pp.



Generated on 2024-09-19 17:49 GMT / https://hdl.handle.net/2027/osu.32435030643837
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

Sulzer Item 3 (000413 - 000431)

"The Sulzer Single-Tube Steam Generator," by Prof. A. Stodola. Reprinted from "The Engineer," Nov. 17/24, 1933. 19 pp. 5415e - 500 I. 34.

Sulzer Item 4 (000432 to 000436)

"High-Pressure Primary Plant with Sulzer monotube steam generator for the Power Station of a British Colliery". Copy of typed memo with figures. February 11, 1936. 3076 IX. 1935.

Sulzer Item 5 (000437 to 000443)

"The Monotube Boiler in S. S. 'Kertosono'". Reprint from "The Engineer" June 5, 1936. 7 pp. 5822e. VII. 1936. 500.

Sulzer Item 6 (000444 to 000452)

"The Sulzer Monotube Steam Generator". Mimeographed text plus figure. Oct. 27, 1937. 9 pp.

Sulzer Item 7 (000453 to 000461)

"100-Atm. Steam Power Plant with Sulzer Monotube Steam Generator and Reciprocating Steam Engines," by C. Veit. This article was originally published in "Zeitschrift des Vereins Deutscher Ingenieure," Berlin, vol. 81, No. 81, and later in Technical Review, Sulzer No. 2, 1938. 9 pp. 5873e.

Sulzer Item 8 (000462 to 000465)

"High-Pressure Steam Plant with Sulzer Monotube Steam Generators in a Cardboard Factory in England". Reprinted from Sulzer Technical Review. No. 2, 1940. 5921e.

Sulzer Item 9a (00772)

Cover page of "Elektrizitätsverwertung -- L'Électrique " (Electrical Service, 20th year, Nos. 1-3, April-June 1945. 1 p.

Sulzer Item 9b (00773)

Contents page of same. 1 p.

Sulzer Item 9c (00774 to 00775)

"Wasserkraft und Kohle; Force hydraulique et charbon; Water power and coal." Editorial, pp. 1-2. 2 pp.



Generated on 2024-09-19 17:46 GMT / https://hdl.handle.net/2027/osu.32435030643837
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

Sulzer Item 9d (00776 to 00781)

"Das Energieproblem im Lichte neuzeitlicher Forschung: Le problème de l'énergie, à la lumière des recherches scientifiques récentes: Energy as seen by modern science," by Prof. Dr. Franz Tank, ETH, Zurich. German-language article with half-page summaries in French and English. Pages 3 to 8. 6 pp.

Sulzer Item 9e (00782 to 00785)

"Der Einsatz von Wasserkraft und Kohle in die Bedarfsdecking Betrachtungen zur schweizerischen Energiewirtschaftspolitik: L'emploi des forces hydrauliques et du charbon pour couvrir los besoins en énergie: Meeting the demand for energy by means of water power and coal," by Prof. Dr. Bruno Bauer, ETH, Zurich. German-language article with half-page summaries in French and English. Pages 9-12, 59. 5 pp.

Sulzer Item 9f (00786 to 00803)

"Planung von Kessel- und Speicheranlagen für industrielle Wärmezentralen Unter Berücksichtigung der Energieerzeugung im Gegendruckbetrieb: Les projets d'installations de chaudières et d'accumulateurs pour centrales industrielles de production de chaleur, compte tenu de production d'énergie en exploitation a contre-pression: Planning boiler and accumulator plants for industrial power stations, with special reference to back-pressure energy production," by Dir. J. Gastpar, Winterthur. German-language article with half-page summaries and titles to figures in French and English. Pages 42-59. 18 pp.

Sulzer Item 9g (00804 to 00814)

"Heizkraftanlagen mit Gegendruck-Kolbendampfmaschinen: Production de chaleur et de force matrice dans des installations pourvries de machines a vapeur a piston fonctionnant avec contre-pression: Combined heating and power plants with back-pressure, piston-type steam engines" by H. Nyffenegger, Obering, Winterthur. German-language article with half-page summaries and titles to figures in French and English. Pages 60-68, 80, 92. 11 pp.

Sulzer Item 10 (000466 to 000512)

"Carried-Out High-Pressure Steam Plants." An assembly of photographs and drawings showing sectional views, plant arrangements, and details of the various features. 47 pp.

Sulzer Item 11 (000513)

No. 898129 - A large folded diagram of a high-pressure steam plant with reheater similar to fig. 32 (p. 52) of Item 9f above.



Generated on 2024-09-19 17:47 GMT / https://hdl.handle.net/2027/osu.32435030643837
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

Sulzer Item 12a (000514 to 000529)

"Sulzer Hochdruckanlagen mit Trommellosem Einrohrdampfkessel und Selbsttätiger Regelung." (For translation, see Item 12b below.) 16 pp. 5417-1.

Sulzer Item 12b (000530 to 000538)

"Sulzer High-Pressure Plant with Drumless Monotube Steam Generator and Automatic Regulation." A typed translation of Item 12a above. 9 pp. 5417e-1.

Sulzer Item 13 (000539 to 000542)

"Sulzer High-Pressure Steam Plant with Monotube Steam Generator." 4 pp. 5898e.

Sulzer Item 14 (000543 to 000548)

"Measurement of the Salt Content in the Boiler Feed-Water of Industrial Monotube Steam Generator Plants." 6 pp. 308e. Bch. 1.

Sulzer Item 15 (000549 to 000551)

"High-Pressure Installations Equipped with Sulzer Monotube Steam Boilers." Typed memo, Sept. 27, 1945. 3 pp.

Sulzer Item 16 (000552 to 000555)

"List of Sulzer Monotube Steam Generators in Service or under Construction." Mimeographed list of 51 installations, undated. Obtained September 27, 1945. 4 pp.

Sulzer Item 17a (000556 to 000563)

Front and inside cover of "Technical Review Sulzer," No. 2, 1945, and "A New Method for the Treatment of Regulation Problems," by Dr. P. Profos, Pp. 1 to 6. 8 pp.

Sulzer Item 17b (000563 to 000567)

"The Oil-free Reciprocating Compressor as a Heat Pump," by O. Walti. Pp. 6 to 10. 5 pp.

Sulzer Item 17c (000567 to 000572)

"Centrifugal Pumps in Heat Pump Plants," by J. Sprecher. Pp. 10 to 15. 6 pp.

Sulzer Item 17d (000572 to 000596)

"The Economy of Concentrating Plants With and Without Heat Pumps," by W. Wittwer. Pp. 15 to 19. 5 pp.



Generated on 2024-09-19 17:53 GMT / https://hdl.handle.net/2027/osu.32435030643837
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

Sulzer Item 17e (000577 to 000582)

"The Past and Future of the Steam Engine," by O. Walti. Pp. 20 to 25. 6 pp.

Sulzer Item 18 (000588 to 000607)

"Sulzer Examples of Work Done by the 'Boiler, Apparatus and Plate Work Department'." 98 pictures or diagrams of types of equipment built, with brief explanatory statement about each. 20 pp. 5903e.

Sulzer Item 19 (000608 to 000623)

"Sulzer Products." A summary, with illustrations. 16 pp. 5949e.

Sulzer Item 20a (000624 to 000630)

"Sulzer Technical Review." No. 1, 1945. "This number is devoted to the opening of Sulzer Bros. Central Research Laboratory at Winterthur." Cover, frontispiece, contents, and foreword by D. Sc. Tech. F. Oederlin, managing director. Pp. 1-5. 7 pp.

Sulzer Item 20b (000631 to 000667)

"Brittleness and Toughness of Metals at High Temperatures," by Dr. W. Siegfried. Pp. 43-79. 37 pp.

Sulzer Item 20c (000668 to 000676)

"The Oscillographic Equipment of the New Physical Laboratory," by Dr. W. Marti. Pp. 80-88. 9 pp.

Sulzer Item 20d (000677 to 000689)

"The New Sulzer Research Laboratory." Pp. 140 to 152. 13 pp.

Sulzer Item 21 (000690 to 000741)

"Sulzer Strahlungs Heizung-System Crittall." (Sulzer Radiation Heating, Crittall System.) 34 + 2 pp. + 14 pp. of loose copies of testimonial letters in German or French. Z. No. 6008 A dd - 40.

Sulzer Item 22 (000742 to 000754)

"Sulzer Einige Referenzen über wärmetechnische Anlagen." (A few references on Sulzer radiation-heating installations.) Names and locations of nearly 100 installations, with length of heating coil. Z. No. 5740-D.dc 30 - Z. No. 6008.A.C.-dd-3.



Generated on 2024-09-19 17:48 GMT / https://hdl.handle.net/2027/osu.32435030643837
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

Sulzer Item 23 (000755 to 000760)

"Sulzer Zentral Heizungen" (Sulzer Central Heating). Collection of small pictures of buildings containing central heating plants, air conditioning, district heating, and ventilating installations, 6 pp. Z. No. 4644-V. 34.

## APPENDIX

For bibliographic references to the publications cited, see the three lists of "Documents and Publications" following Parts I, II and III of this report. These documents have been microfilmed on T.O.M. reel 139, original designation SF 6.

No tables or illustrations accompany this report.

## PERSONNEL OF TEAM

The information contained in this report was obtained by Dr. Harold J. Rose, (U.S.), Scientific Consultant for F.E.A.-T.I.I.C.



Generated on 2024-09-19 17:46 GMT / https://hdl.handle.net/2027/osu.32435030643837
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google

Digitized by Google

Original from
THE OHIO STATE UNIVERSITY